Journal of Forestry Research (2014) 25(2): 429–435
DOI 10.1007/s11676-014-0472-z

ORIGINAL PAPER

Goal programming approach for sustainable forest management (case study in Iranian Caspian forests)

Soleiman Mohammadi Limaei • Maryam Seddigh Kouhi
Teymour Rostami Sharaji

Received: 2013-07-15 Accepted: 2013-08-12

Abstract: We used a goal programming technique to determine the optimal harvest volume for the Iranian Caspian forest. We collected data including volume, growth, wood price at forest roadside, and variable harvesting costs. The allometric method was used to quantify sequestrated carbon. Regression analysis was used to derive growth models. Expected mean price was estimated using wood price and variable harvesting costs. Questionnaire was used to determine the constraints and the equation coefficients of the goal programming model. The optimal volume was determined using the goal programming method according to multipurpose forest management. LINGO software was used for analysis. Results indicated that the optimum volumes of species were 250.25 $m^3 \cdot ha^{-1}$ for beech, 59 $m^3 \cdot ha^{-1}$ for hornbeam, 73 $m^3 \cdot ha^{-1}$ for oak, 41 $m^3 \cdot ha^{-1}$ for alder, and 32 $m^3 \cdot ha^{-1}$ for other species. The total optimum volume is 455.25 $m^3 \cdot ha^{-1}$.

Keywords: goal programming, sustainable forest management, carbon sequestration, Iranian Caspian forests

Introduction

The forestry sector is well positioned to provide worldwide leadership in sustainable development. The forestry community is accustomed to long-term perspectives; it is knowledgeable about responses of forest ecosystems to natural and human disturbances; it is comfortable with the sustained yield principle; and, in a few instances, it has attempted to practice multiple-use and integrated-use of forests (FAO 2013).

The online version is available at http:// www.springerlink.com

Soleiman Mohammadi Limaei (✉), Maryam Seddigh Kouhi,
Teymour Rostami Sharaji
Department of Forestry, Faculty of Natural Resources, University of Guilan, Someh Sara, P.O. Box, 1144, Iran. E-mail: limaei@guilan.ac.ir

Corresponding editor: Zhu Hong

Sustainable forest management is the management of forests, based on the principles of sustainable development. Sustainable forest management seeks to achieve social, economic and environmental goals.

Traditional forest planning sought achievement of economic goals such as maximizing Net Present Value (NPV) through timber harvest or enhancing environmental protection. Less attention was given to multipurpose goals because, in many cases, these goals conflicted with each other and it seemed impossible to accomplish them simultaneously. In the face of diminishing forest resources but increasing management capacities, forest management is shifting toward a multipurpose approach from which optimal results can be obtained from minimal resources. There are three main goals in forest management: (1) Economic goal: Related to harvest of timber and non timber resources; (2) Social goal: Including satisfying social needs such as maximizing employment, satisfying needs of forest residents and people living in the forest neighborhood; (3) Environmental goal: Including maximizing of carbon sequestration and protection of soil and water resources.

During the last two decades, the importance of sustainable forestry has increased. The concept of “sustainable” means that, forest resources should be used today in ways that do not compromise their use in future. The concept of forestry has shifted from sustainable product to sustainable ecology, sustainable economy and society. In fact as time elapse, the importance of products and services related that are related to forests increases (Nouri et al. 2010). Today managing the sustainability of forests is considered as the contribution of the forestry in sustainable development (Higman et al. 2005).

Improving living condition of animals dependent to forest ecosystem, as well as conserving variety of forest stands are among the main goals of modern forestry (Pommerening 2002). It also means, managing and using forest resources in a way that biological diversity, production and the possibility of potential production of forests according to its ecological capacities would be saved and no harm would be threading other ecosystems (Bernasconi 1996).

One of the mathematical techniques that could handle a multipurpose problem is Goal Programming (GP). GP is a special case of linear programming (Kangas et al. 2008). It was first described by Charnes and Cooper (1961). A forestry application of GP was first presented by Field (1973). After that, several applications of GP to forest management planning was presented (D´ıaz-Balteiro and Romero 2003). Mendoza (1987) provided an overview of GP formulations and extensions with special reference to forest planning. Tamiz et al. (1998) provided a more general overview of GP elaborations and applications. Some crucial problems of standard linear programming can be avoided using GP model. However, the GP problem is solved similarly as in standard linear programming.

Bettinger et al. (2009) mentioned the application of GP model to the following cases:

- Determination of present and future production from the land, as well as the demand for the different products.
- Estimation of physical capacity of the land to produce the various products.
- Analyze the complementary and competitive relationships among the goals.
- Determination the feasible set of desirable goals.
- Express the goals as a single objective function, and design the problem formulation using the appropriate constraints.

Gomez et al. (2006) used GP method to create balance among the diameter classes in Cuba's forest, the forest was extremely harmed due to natural disasters and harvesting.

Samghabadi et al. (2004) Developed a mathematical model for sustainable forest development by strategic land use planning in Ramsar watershed in north of Iran. At their research, GP is used for modeling. Their results indicated that it is possible to reach the optimum goals such as maximization of carbon sequestration, NPV of income, stand volume, employment and minimization of soil erosion. We undertook a research project to develop a model for sustainable forestry in Iran based on the concept of sustainability defined by Report of the World Commission on Environment and Development (WCED) (1987). Therefore, GP model was applied to determinate the optimum standing timber or volume based on multi criteria decision making in Shafaroud forest, Iranian Caspian forests, and north of Iran.

Materials and methods

Study area

We collected data from district number 11 at Shafaroud forest in north of Iran. These forests are located in mountainous area and its altitude ranges from 500 to 1650 m. This district consists of 45 compartments and its cover 2202.9 ha. Of this, 1887.1 ha are suitable for harvesting, 98.5 ha are protected forests, 143.8 ha are bare land, 0.8 ha is agricultural and residential area, and 72.7 ha are covered by roads. These forests are uneven-aged and the main species are: beech (*Fagus orientalis*), hornbeam (*Carpinus sp*), oak (*Quercus sp*), alder (*Alnus sp*) and etc. This forest is managed under selection system (Fig. 1).

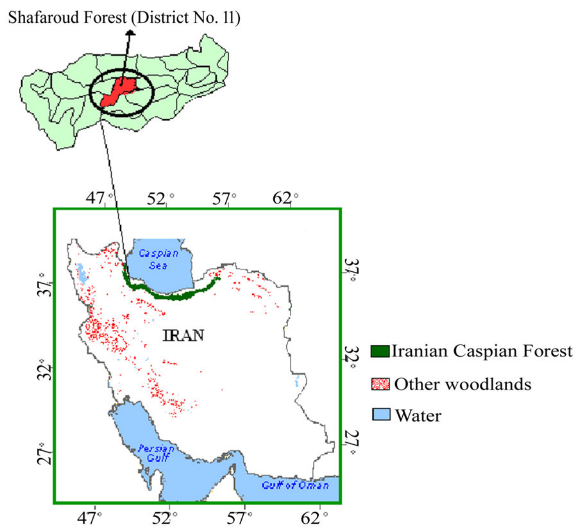

Fig. 1: Iranian forests map (FAO 1999, Global Forest Cover map) and the study area (Shafaroud forest).

The collected data

We collected data including volume, growth, sequestrated carbon, wood price at forest roadside, logging and wood transportation costs, and number of required labor to manage the forest. We used questionnaires in order to weight the different goals in multipurpose forest management.

We obtained volume and growth data from previous research (Bonyad 2005), (Table 1). We obtained sequestrated carbon data using allometric equations (Kabiri Koupaei 2009).

Table 1: Volume and growth of different species at Shafaroud uneven-aged forest, north of Iran (Bonyad 2005)

Species	Volume ($m^3 \cdot ha^{-1}$)	Growth ($m^3 \cdot ha^{-1} \cdot a^{-1}$)	Species	Volume ($m^3 \cdot ha^{-1}$)	Growth ($m^3 \cdot ha^{-1} \cdot a^{-1}$)
Beech	14.8	0.733	Alder	0.537	0.0112
	30.9	0.462		2.316	0.0789
	31.2	0.313		6.392	0.2216
	32.1	0.805		6.923	0.2219
	33.4	0.397		9.411	0.2418
	44.6	0.878		33.537	0.5156
	75.5	1.339			
	122.4	2.878			
Hornbeam	6.758	0.394	Other species	0.0196	1.083
	7.46	0.064		0.0431	2.54
	8.286	0.232		0.0439	2.962
	10.925	0.192		0.106	3.16
	11.605	0.146		0.1066	6.585
	15.044	0.626		0.2126	9.745
	22.504	0.69		0.6867	14.908
	45.034	1.028		0.8992	24.63
Oak	1.125	0.046			
	2.456	0.058			
	4.967	0.149			
	5.966	0.1708			
	7.118	0.2168			
	8.779	0.2043			

Growth function

We assumed that annual growth is a function (f) of volume (Mohammadi Limaei 2006):

$$G = f(V) \tag{1}$$

where, G is growth ($m^3 \cdot ha^{-1} \cdot a^{-1}$), V is stock level ($m^3 \cdot ha^{-1}$). We used regression analysis to estimate the growth function.

Carbon sequestration

We used the allometric method to determine the above ground stand sequestrated carbon. At this method, first of all we determined the biomass of stand, then we considered 50% of dry stand weight as the amount of sequestrated carbon (Snowdon et al. 2002). The most commonly used mathematical model for biomass studies is $Y = aD^b$, where, a and b are the scaling coefficients, Y is the total above ground tree dry biomass and D is the diameter at breast height. Value a and b reported to vary with species, stand age, site quality, climate, and stocking of stands (Baskerville 1965). According to the above mentioned method, we estimated the amount of sequestrated carbon using the allometric functions determined by Kabiri Koupaei (2009).

Expected mean price

We derived the stumpage price data from actual timber, roundwood, fire and pulpwood prices at forest roadside minus the variable harvesting costs. Then we adjusted it by consumer price index (CPI) for the base year 2004. We used regression analysis to predict the price processes. We used the estimated parameters from regression analysis to determine the expected mean price using the following equation (Mohammadi Limaei 2011).

$$P_{eq} = \frac{\alpha}{1-\beta} \tag{2}$$

where, P_{eq} is the expected mean price, α and β are the estimated parameters.

Goal programming (GP) model

A GP model, similar to the LP model consist an objective function and constraints. It can be thought of as an extension or generalization of LP to handle multiple objectives. Each of these objectives is given a goal or target value to be achieved. Unwanted deviations from this set of target values are then minimized in an achievement function. In GP, all the objectives are handled in the same manner: they are expressed by goal constraints. A goal constraint includes goal variables that measure the amount by which the contribution of all activities to the goal in question falls short or exceeds the goal level (i.e. the right hand side of the constraint). The objective function of a GP problem is to minimize the sum of the (weighted) deviations from all target levels associated with the management goals. When goal variables are included in a constraint, the problem of infeasibility linked to the constraint is avoided (Kangas et al. 2008). The following function is the GP objective function:

$$\min z = \sum_{i=1}^{G} (W_i^- D_i^- + W_i^+ D_i^+) \tag{3}$$

The deviations can be weighted according to their importance, in the objective function W_i^- is the weight given to each unit of underachievement deviation (D_i^-); W_i^+ is the weight given to each unit of overachievement deviation (D_i^+). The weights can be interpreted to have two separate roles in the problem. As scaling factors, weights W_i^- and W_i^+ reduce deviations expressed in different measurement units to a common unit of measurement. As importance weights, they describe the relative importance's of the goal variables. Because of these intermingling roles, the interpretation of weights as relative importance of goals, respectively, is not unambiguous (Kangas et al. 2008).

The weights fulfill two purposes. They express all deviations from goals in a common unit of measurement, and they reflect the relative importance of each goal (Buongiorno and Gilless 2003). Deviations that concern the decision makers most get the larger weights relative to the others. Deviations that are of no concern or are looked at favorably may be omitted from the objective function altogether (Buongiorno and Gilless 2003). The choice of weights for objective function (3) can be simplified by considering the relative, rather than the absolute, deviations with respect to goals. The new expression of the objective function is then:

$$\min \quad z = \sum_{i=1}^{G} \frac{u_i^- D_i^- + u_i^+ D_i^+}{g_i} \tag{4}$$

where, each weight u_i (u_i^- , u_i^+) applies to a relative deviation from goal i . A GP model has at least some constraints, called goal constraints that contain goal variables. The goal variables measure the deviation between management goal levels and actual outcomes. The general formulation of goal constraints is (Buongiorno and Gilless 2003): and X_j, D_i^- , D_i^+ >=0

$$\sum_{j=1}^{n} a_{ij} X_j + D_i^- - D_i^+ = g_i \qquad for \;\; i = 1,...,G \tag{5}$$

where, X_j is the jth activity (decision) variable. a_{ij} is the (constant) contribution to goal i per unit of activity j The g_i is a constant measuring the target of goal i, of which there are G. As long as both D_i^- and D_i^+ are present in a goal constraint, no infeasibility may result from that constraint. The goal variables always fill the gap between the goal level and what is actually achieved.

Other constraints may be present, of the usual LP variety; that is (Buongiorno and Gilless 2003):

$$\sum_{j=1}^{n} a_{ij} X_j \leq, =, or \geq b_i \qquad \text{for } i = G+1, \ldots, m \tag{6}$$

D_i^- is the underachievement deviation variable and D_i^+ is the overachievement deviation variable in the objective function and in the goal constraints. Minimizing the differences ensures that one of these deviation variables is always zero, and the other can deviate from zero. If the underachievement variable is greater than zero, then amount D_i^- needs to be added to the left hand side of the constraint in order to achieve the target level G_j for goal i, and if D_i^+ is greater than zero, this amount needs to be subtracted from it to achieve the goal (Kangas et al. 2008).

Formulating of GP model

We used functions 3 to 6 to determine the optimal standing timber in the study area. We determined the constraints and objective function of GP model as below:

Constraint functions

First of all, we determined the following functions as the constraints:

$$X_1 + X_2 + X_3 + X_4 + X_5 \geq 457 \tag{7}$$

Equation 7 is a constraint that shows the minimum total feasible volume ($m^3 \cdot ha^{-1}$) that obtained from questionnaires. Where X_1 is volume of beech, X_2 is volume of hornbeam, X_3 is volume of oak, X_4 is volume of alder and X_5 is volume of the other species.

$$X_1 \geq 251 \tag{8}$$

Equation 8 is minimum feasible volume of beech. It should be equal or more than 251 $m^3 \cdot ha^{-1}$ that determined from questionnaires.

$$X_2 \geq 59 \tag{9}$$

Equation 9 is minimum feasible volume of hornbeam. It should be equal or more than 59 $m^3 \cdot ha^{-1}$ that determined from questionnaires.

$$X_3 \geq 73 \tag{10}$$

Equation 10 is minimum feasible volume of oak. It should be equal or more than 73 $m^3 \cdot ha^{-1}$ that determined from questionnaires.

$$X_4 \geq 41 \tag{11}$$

Equation 11 is minimum feasible volume of alder. It should be equal or more than 41 $m^3 \cdot ha^{-1}$ that determined from questionnaires.

$$X_5 \geq 32 \tag{12}$$

Equation 12 is minimum feasible volume of other species. It should be equal or more than 41 $m^3 \cdot ha^{-1}$ that determined from questionnaires.

$$0.279 X_1 + 0.322 X_2 + 0.377 X_3 + 0.244 X_4 + 0.333 X_5 \geq 137 \tag{13}$$

Equation 13 is minimum feasible sequestrated carbon ($t \cdot ha^{-1}$). The coefficients for decision variables (X_1 to X_5) are the sequestrated carbon that calculated for each species.

$$0.0116 X_1 + 0.019 X_2 + 0.0055 X_3 + 0.011 X_4 + 0.024 X_5 \geq 5.66 \tag{14}$$

Equation 14 is minimum feasible growth per hectare that calculated by volume per hectare. The coefficients for X_1 to X_5 are growth per hectare that calculated for each species.

$$0.0525 X_1 + 0.0525 X_2 + 0.0525 X_3 + 0.0525 X_4 + 0.0525 X_5 \geq 24 \tag{15}$$

Equation 15 is the minimum feasible personnel or labor based on forest management plan (Iranian Forests, Rangeland and Watershed Management Organization 1999). The coefficients for X_1 to X_5 are the amount of labor to manage one cubic meter of stock and it is assumed to be equal for all species.

$$767.33X_1 + 397.56X_2 + 537.46X_3 + 675.90X_4 + 643.2\ 5X_5 \geq 304167 \tag{16}$$

Equation 16 is minimum acceptable NPV of stock (10000 Iranian Rials) that is determined based on stumpage price, volume, growth and rate of interest. The coefficients for X_1 to X_5 are the NPV calculated for each species (10000 Iranian Rials).

We determined the negative or positive deviation from goal based on the constraints properties. If the initial constraint or inequality is greater than a quantity, then the negative deviation should be included in the equation. This negative deviation should be written on the left hand side of the equation and the inequality will be changed to equality. In case the initial constraint is less than a quantity, then positive deviation should be subtracted from left hand side of the equation. On the other hand,

the signs D_I^- or D_I^+ can be added to relations 7 to 16 in the different above mentioned cases. According to the properties of the constraints at this study, we did not have any positive deviation from the goal. Consequently, the following new equations are determined:

$$X_1 + X_2 + X_3 + X_4 + X_5 + D_{\mathrm{vt}}^- = 457 \quad (17)$$

$$X_1 + D_{\mathrm{F}}^- = 251 \quad (18)$$

$$X_2 + D_{\mathrm{CAR}}^- = 59 \quad (19)$$

$$X_3 + D_{\mathrm{Q}}^- = 73 \quad (20)$$

$$X_4 + D_{\mathrm{A}}^- = 41 \quad (21)$$

$$X_5 + D_0^- = 32 \quad (22)$$

$$0.279\, X_1 + 0.322\, X_2 + 0.377\, X_3 + 0.244\, X_4 + 0.333\, X_5 + D_{\mathrm{c}}^- = 137 \quad (23)$$

$$0.0116\, X_1 + 0.019\, X_2 + 0.0055\, X_3 + 0.011\, X_4 + 0.024\, X_5 + D_{\mathrm{G}}^- = 5.66 \quad (24)$$

$$0.0525X_1 + 0.0525X_2 + 0.0525X_3 + 0.0525X_4 + 0.0525X_5 + D_{\mathrm{MINP}}^- = 24 \quad (25)$$

$$767.33X_1 + 397.56X_2 + 537.46X_3 + 675.90X_4 + 643.25X_5 + D_{\mathrm{NPV}}^- = 304165 \quad (26)$$

where, D_{VT} is negative deviation of total volume, D_{F} is negative deviation of beech volume, D_{CAR} is negative deviation of hornbeam volume, D_{Q} is negative deviation of oak volume, D_{A} is negative deviation of alder volume, D_{O} is negative deviation of other species volume, D_{C} is negative deviation of sequestrated carbon, D_{G} is negative deviation of growth per hectare, D_{MINP}^- is negative deviation of labor, D_{NPV} is negative deviation of NPV of volume.

Objective function

The aim of objective function was to minimize the unfavorable deviation from the goal. Therefore, the following function was determined:

$$\min z = D_{\mathrm{VT}}^- + D_F^- + D_{\mathrm{CAR}}^- + D_{\mathrm{Q}}^- + D_{\mathrm{A}}^- + D_{\mathrm{O}}^- + D_{\mathrm{C}}^- + D_{\mathrm{G}}^- + D_{\mathrm{MINP}}^- + D_{\mathrm{NPV}}^- \quad (27)$$

$$\min z = 21.88D_{\mathrm{VT}}^- + 39.79D_{\mathrm{F}}^- + 168.32D_{\mathrm{CAR}}^- + 136.76D_{\mathrm{Q}}^- + 243.13D_{\mathrm{A}}^- + 312.6D_{\mathrm{O}}^- + 72.81D_{\mathrm{C}}^- + 1767.43D_{\mathrm{G}}^- + 416.67D_{\mathrm{MINP}}^- + 0.0329D_{\mathrm{NPV}}^- \quad (28)$$

Finally we solved the GP model consisting of objective function and constraints using LINGO software.

Results

Growth function

Results of regression analysis showed that the logarithmic equation is the best model to predict the growth function based on the collected data. The growth equations are shown in Table 2. It should be noted that in all of the equations at Table 2, Y is average growth ($\mathrm{m^3 \cdot ha^{-1} \cdot a^{-1}}$) X is volume ($\mathrm{m^3 \cdot ha^{-1}}$). All of the functions were significant at significance level of 0.05.

Table 2: Growth functions of different species.

Species name	Function	R^2
Beech	Y=1.0551ln(X) – 2.9109	0.65
Hornbeam	Y=0.4579ln(X) – 0.7522	0.77
Oak	Y=0.0906 ln(X) + 0.0115	0.90
Alder	Y=0.1186 ln(X) + 0.0086	0.86
Other species	Y=0.2804 ln(X) – 2021	0.74

Expected mean price

Expected mean prices of different species are determined using Eq. (2) and the estimated parameters of regression analysis (Table 3).

Table 3: Estimated parameters based on regression analysis for stumpage price and expected mean price of different species.

Species	Estimated parameters		
	α	β	Expected mean price*
Beech	21.823	0.763	92.08
Hornbeam	14.074	0.705	47.708
Oak	23.025	0.643	64.496
Alder	20.196	0.751	81.108
Others	19.143	0.752	77.19

Notes: * Expected mean price is 10000 Iranian Rials·m^{-3}. α and β are the estimated parameters from regression analysis.

Carbon sequestration

We determined the relation between sequestrated carbon ($\mathrm{t \cdot ha^{-1}}$) (Y) and volume ($\mathrm{m^3 \cdot ha^{-1}}$) ($X$) based on the allometric function for

different species (Table 4). All of the functions were significant at the significance level of 0.05 and R^2 =0.99.

Table 4: Carbon sequestration functions of different species.

Speices name	Function
Beech	Y=0.2787X – 0.041
Hornbeam	Y=0.3219X – 0.0161
Oak	Y=0.3764X – 0.003
Alder	Y=0.2443X – 0.0149
Other speices	Y=0.3334X – 0.0163

Goal programming model

The results of GP model is shown in Table 5 that solved by LINGO software. It indicates that optimum volume of beech is 250.25 $m^3 \cdot ha^{-1}$ and its negative deviations from the goal is 0.75 $m^3 \cdot ha^{-1}$.

Table 5: Results of goal programming model solved in LINGO software

Variable	Value	Reduced cost
D_{VT}	1.745520	0.000000
D_F	0.7455197	0.000000
D_{CAR}	0.000000	109.5167
D_Q	0.000000	33.21138
D_A	0.000000	215.4910
D_O	0.000000	265.6195
D_C	0.000000	536.2241
D_G	0.1554803E-01	0.000000
D_{MINP}	0.9913978E-01	0.000000
D_{NPV}	1150.710	0.000000
X_1	250.2545	0.000000
X_2	59.00000	0.000000
X_3	73.00000	0.000000
X_4	41.00000	0.000000
X_5	32.00000	0.000000
Row	Slack or Surplus	Dual Price
1	174.5032	-1.000000
2	0.000000	-21.88000
3	0.000000	-39.79000
4	0.000000	-58.80326
5	0.000000	-103.5486
6	0.000000	-27.63901
7	0.000000	-46.98046
8	0.000000	463.4141
9	0.000000	-1767.430
10	0.000000	-416.6700
11	0.000000	-0.3290000E-01

Notes: D_{VT} is negative deviation of total volume, D_F is negative deviation of beech volume, D_{CAR} is negative deviation of hornbeam volume, D_Q is negative deviation of oak volume, D_A is negative deviation of alder volume, D_O is negative deviation of other species volume, D_C is negative deviation of sequestrated carbon, D_G is negative deviation of growth per hectare, D_{MINP} is negative deviation of labor, D_{NPV} is negative deviation of NPV of volume.

Optimum volume of hornbeam, oak, alder and the other species are 59 $m^3 \cdot ha^{-1}$, 73 $m^3 \cdot ha^{-1}$, 41 $m^3 \cdot ha^{-1}$ and 32 $m^3 \cdot ha^{-1}$, respectively. There negative deviations are zero. It means they exactly meet the goal.

Finally we calculated the total optimum volume based on the obtained result that is 455.25 $m^3 \cdot ha^{-1}$.

Results also show that there were no slack or surplus for all the constraints. But the constraints such as carbon sequestration, labor, and growth exactly meet the goals without any deviations. Results also show that the constraints such as NPV, beech volume and total volume don't meet the goals without adding the deviations. Therefore, the negative deviation of NPV is 1150.710 (10000 Iranian Rials). The negative deviation of total volume and beech volume are 1.75 $m^3 \cdot ha^{-1}$ and 0.75 $m^3 \cdot ha^{-1}$), respectively.

Conclusions

This research was carried out in order to determine the optimal volume based on different factors such as sequestrated carbon, minimum acceptable labor, growth, NPV of stand. D´ıaz-Balteiro and Romero (2003) used GP in order to determine the optimal forest management concerning carbon sequestration in Spain. The goal at their model was maximizing NPV, harvested volume control, area control at different ages and final volume. They used 8 scenarios to solve the model that different goals vary at different scenarios. Hence, there is some similarity between the results of their model and this research.

Gomes et al. (2006) used GP model for timber harvest scheduling problem in order to obtain a balanced age class distribution of a forest plantation in Cuba. This forest was destroyed by natural disaster and over exploitation. The main goal was to organize and regulate the forest. This involves a significant change from its current distribution by ages to obtain a more even-aged structure over a planning horizon of 25 years which coincides with the rotation age. The proposed model aims to archive the new distribution while bearing in mind the economic aspects of the forest as well as other factors. They obtained several solutions that provided a regulated forest while respecting the economic and other targets of the decision-makers.

Samghabodi et al. (2004) developed a GP model by strategic landuse planning for a watershed in north of Iran. They used multi-criteria optimization for modeling. The objective function was maximization of carbon sequestration, NPV of income, stand volume, maximizing employment and minimization of soil erosion. They used Lp-norm to aggregate the objectives. There is some similarity between the results of their research and this paper, but the environmental factor was different at these two researches. They used soil erosion as an environmental factor whereas at this research carbon sequestration is used as an environmental factor for GP modeling.

Dı´az-Balteiro and Romero (2003) used GP model for forest management when carbon capture is considered in Spanish forest ``Pinar de Navafrı´a'' located in the mountains of ``Sierra de Guadarrama'' near Madrid. The results reveal difficulty in ob-

taining from an economic and forestry viewpoint good harvest schedules compatible with high levels of carbon captured.

Chang et al. (2009) used the multi-criteria to solve a real-world, revitalization strategies project selection problem for the historic Alishan Forest Railway in Taiwan by using fuzzy Delphi, analytic network process, and zero-one goal programming. They suggested an improved methodology, one that uses an integrated approach and reflects the interdependencies between the evaluation criteria and candidate projects. The management of the Alishan Forest Railway has implemented the processing system proposed by their research and suggested to the government the best alternative strategies.

However, GP model is one of the techniques that could handle the multipurpose management, as it was discussed before. This technique applied to solve forest management problems with different goals and criteria at different countries. The decision makers can use this method for sustainable forest management to consider economics, environmental and social aspects of forest management.

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